

1. On 35 mm motion-picture film (negative) two to three virtually white images, often up to three such sequence changes at short intervals (approximately three images) one after the other;
2. On video tape up to 30 virtually black images;
3. On video tape, at the end of the sequence, 10 to 15 - disregarding noise - identical individual images, then start of the next sequence without specially marked intermediate images.

The first two sequence changes (1 and 2 above) are designated below as sequence changes of the first type, and the third sequence change (3 above) is designated below as a sequence change of the second type. The sequence changes of the first and second types are handled as follows:

Sequence changes of the first type, which are based on a great change in the mean brightness, can be identified very reliably, i.e. with good image material it is possible to achieve an identification rate of 100%.

Separation of image sequences is effected by setting separation markers of first and second types or sequence changes of the first and second types. A separation marker of the first type is a predetermined number of successive black or white images. The images identified as separation markers are themselves not stored. The first image after the separation marker is also the first image of the next sequence. The sequences themselves must contain at least a predetermined number of images, otherwise they are discarded.

Sequence changes of the second type, which are based on a change in the image content, are significantly more difficult to identify than sequence changes of the first type since the size of the change varies and large deviations between successive images can occur even within a sequence. In many applications, an identification rate of only approximately 75% is achieved for sequence changes of the second type, i.e. not all sequence changes are identified as such and occasionally separation is performed within a sequence. However, even if this occurs, it is guaranteed that no images are lost.

The separation is effected according to the following rules:

- a) A separation marker of the second type is an image whose content differs greatly from the contents of its preceding images;
- b) Separation markers of the first type always have priority over separation markers of the second type;
- c) Separation markers of the second type that are situated within a predetermined number of images from separation markers of the first type are not taken into account;
- d) A separation marker of the second type is not taken into account if its preceding sequence does not contain at least a predetermined number of images;
- e) An image identified as a separation marker is the first image of the next sequence.

To set the behavior of the automatic separation method, the most important parameters - specified below - and also the following file names are set or specified in a file "splitter.ini":

- a) The parameter **MeanMinFrames** specifies the minimum number of images that must be contained in the individual sequences that are terminated by separation markers of the first type. Sequences that have less than the minimum number of images are discarded. Since many films only contain very short sequences with the insertion of the patient's name (clapperboard), given an internal predetermined value of 12 and a range of values  $> 0$ , a range of values for this parameter of 4 to 6 is recommended.
- b) The parameter **MeanSpltFrames** specifies the minimum number of images that a separation marker of the first type must comprise in order that separation is performed. This predetermined value is 2, the range of values is  $> 0$ .
- c) The parameter **MeanSensitivity** indicates the response sensitivity for separation markers of the first type from low to high with a range of values from 0.0 to 1.0. The value 0.0 denotes no checking for this criterion. In order that the beginning of a new sequence whose brightness differs greatly from that of the preceding sequence can be reliably identified, this value must not, however, be too high. Within the range of values specified above, a range of values from 0.25 to 0.35 is recommended.
- d) The parameter **ChangeMinFrames** specifies the minimum number of individual images that must be contained in sequences that are

terminated by separation markers of the second type. When a sequence has less than the minimum number of individual images, the separation marker is discarded. Moreover, all separation markers of the second type are discarded which do not have at least this minimum number of individual images from separation markers of the first type. Preferably, this predetermined value is 12 given a range of values of  $> 0$ .

- e) The parameter **ChangeSensitivity** indicates ~~the~~ response sensitivity for separation markers of the second type. Given a range of values from 0.0 to 1.0, where the value 0.0 denotes no checking for this criterion, the value 0.7 is recommended for average video material.
- f) The file **SpItDatpath** ("splitmarks.dat") indicates the file into which a list of separation markers is written. It is preferably valid only for a debug version of the program.
- g) The file **SeqDatPath** ("sequences.dat") denotes the file in which the sequence list is stored unless a different file name was specified on the command line.

The automatic sequence separation can be activated separately for each video source in a set up window of a recording software. It is effected after the storage of the raw data on a hard disk and prior to further processing to form DICOM data records. In this case, the processing speed is approximately 500 to 1000 images per second. The complete path name of the program "splitter.exe" is entered as a parameter in the file VIM. IM of the recording software.

In a standard installation directory for the files "splitter.exe" and "splitter.ini", the following files are generated in accordance with the presetting:

1. A logging file "splitter.log";
2. A list of the separation markers "splitmarks.dat" for a debug version;
3. A list of the individual sequences "sequences.dat".

In order to form the algorithm, each image is firstly examined with regard to separation markers of the first type. If no such marker is found, a search is made for separation markers of the second type. Once a provisional list for the possible separation markers has been created in this way, post-processing is effected in order to determine the individual sequences.

The function CheckSplitMean is used to find the separation markers of the first type. A moving mean value (MeanMean) of the image brightnesses is calculated in each case over the last 16 (MEANFRAMES) images. From said mean value and the parameter mean sensitivity, a lower (LThresh) and upper (UThresh) threshold value are determined as follows:

$$\text{LThresh} = \text{MeanSensitivity} * \text{MeanMean}$$

$$\text{UThresh} = 255 - \text{MeanSensitivity} * (255 - \text{MeanMean})$$

If the mean value of the current image exceeds UThresh, then a white separation marker (SPLT\_WHITE) is set, and if the mean value

of the current image is less than LThresh, then a black separation marker (SPLT\_BLACK) is set. In this case, the mean values of the separation marker images do not enter into the moving average.

The function CheckSplitChange is used to find separation markers of the second type by calculation of the RMS deviation (CurrRmsDiff) of the pixel brightnesses between the current image and the preceding image. A moving mean value (MeanRmsDiff) of the RMS deviations is determined over the last 16 (MEANFRAMES) image changes and from this and from the parameter ChangeSensitivity a threshold value (DiffThresh) is determined as follows:

$$\text{DiffThresh} = (8 - 6 * \text{ChangeSensitivity}) * \text{MeanRmsDiff}$$

If the RMS deviation of the current image change exceeds the threshold value, then a separation marker (SPLT\_CHANGE) is set. RMS deviations of separation markers of the second type enter into the moving mean value, but those of the first type do not.

The function EvaluateSplit is used to determine the individual sequences from the separation marker list with the following proviso:

1. All separation marker sequences of the first type which are shorter than the number MeanSpltFrames of images are discarded.
2. All separation markers of the second type which lie nearer to the remaining separation markers of the first type than ChangeMinFrames images are discarded.

The individual sequences thus formed start

1. with the first image in the file; or
2. with the first image after a separation marker of the first type; or
3. with a separation marker of the second type3;

and end

1. with the last image in the file or
2. with the last image before a separation marker of the first type, if it is at least MeanMinFrames images long, otherwise the sequence is discarded, or
3. with the last image before a separation marker of the second type, if it is at least ChangeMinFrames images long. Otherwise, the separation marker is discarded.